F I N A L   R E P O R T

CONSTRUCTION ALTERNATIVES FOR ELKHEAD DAM RAISE, MOFFAT COUNTY, COLORADO

Prepared for

Colorado River Water Conservation District
Glenwood Springs, Colorado

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URS

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TABLE OF CONTENTS

List of Tables

List of Figures

This report presents the results of an evaluation of three construction alternatives for raising Elkhead Dam. The Colorado River Water Conservation District is considering raising the dam from a crest El. of 6,375 to 6,390 and is interested in either draining the reservoir or lowering the reservoir to a partial pool during construction. The partial pool would have an approximately 30 foot depth of water and allow the existing fish population to remain. Three alternatives were developed during this study:

- Drain the reservoir and breach the dam (Alternative 1) This was considered as the base case and normal construction method
- Lower the reservoir and breach the dam behind a cellular cofferdam (Alternative 2)
- Lower the reservoir and construct a new outlet works through the left abutment (Alternative 3)

A conceptual level design for each of these alternatives was developed to evaluate feasibility and to estimate construction costs. All three alternatives assume a downstream embankment raise, a spillway capable of carrying the routed PMF flow, and a 6 foot diameter low level outlet works with a free-standing intake tower. Grouting of the abutments and foundation will be necessary to address ongoing seepage issues. The existing outlet will be abandoned in-place by grouting. Fish separation measures at the spillway and intake tower were not considered as part of this study.

The first alternative consists of a breach excavated through the main embankment. This is considered the normal construction method for replacing an outlet works. The new outlet works would be installed in the breach. This alternative has the advantage that stream flows can be passed directly through the breach during construction. Borrow for the raise would be obtained from the valley bottom.

Alternatives 2 and 3 assume the reservoir is maintained at elevation 6,333 during construction. Borrow for these alternatives would come from a source to the north of the recreation area. In Alternative 2, a 30-foot high cofferdam is constructed across the breach and the outlet works is constructed to the same configuration as in Alternative 1. In Alternative 3 the outlet works consists of a tunnel through the left abutment and an intake tower in the reservoir adjacent to the left abutment. The second and third alternatives have provisions for fish separation during construction. The advantage of Alternative 2 is that all outlet works construction occurs in an open excavation. The disadvantage of this alternative is that an extensive cofferdam and piping is necessary to dam the reservoir and control stream flows. The advantage of Alternative 3 is that all outlet works construction can be conducted independent of dam construction and a breach of the dam is not necessary.

A conceptual level cost estimate for comparison of alternatives was developed using estimated quantities and current year pricing. The costs are considered conceptual and include percentages for general requirements, G&A, profit, and bond. Approximate increased costs for Alternatives 2 and 3 compared to Alternative 1 are:

- Alternative 2 — $1.044 million
- Alternative 3 — $233 thousand

1.1 PURPOSE AND SCOPE OF STUDY

The Colorado River Water Conservation District (CRWCD) is evaluating the environmental and technical feasibility of enlarging Elkhead Reservoir. The enlargement would be accomplished by raising Elkhead Dam 15 feet. There are several alternatives being considered for maintaining a partial reservoir pool during construction of the raise. The partial pool would allow for continued use of the reservoir and maintaining the existing fish population during the construction period.

This study was conducted to develop a relative cost for maintaining a partial reservoir during construction. Two alternatives to draining the reservoir for construction of the raise were evaluated. The study was conducted in accordance with the URS proposal to the CRWCD dated September 14, 2001.

1.2 EXISTING FACILITY

The Colorado Division of Wildlife constructed Elkhead Dam in 1974 in cooperation with a group called the Yampa Participants. The Yampa Participants included the power companies that owned the Craig Station coal fired power plant. The dam was constructed to create a multi-purpose reservoir. The dam is owned by DOW, but is held in escrow for transfer to the city of Craig. The dam is located on Elkhead Creek, a tributary to the Yampa River, about 10 miles northeast of the city of Craig in Section 16, Township 7, Range 89W, 6th P.M., Moffat County, Colorado. The dam has State Engineer's Id No. DAMID 440126.

The embankment is approximately 90 feet high with a crest length of approximately 1,140 at elevation 6,375. The current embankment is a homogeneous embankment constructed of sandy clay obtained from a borrow pit on the west side of the reservoir. The embankment has downstream and upstream slopes of 2.5H:1V and 3.0H:1V, respectively, and as shown on Figure 2. A vertical drain/filter is connected to a series of finger drains. The 20-foot wide embankment crest is located at El 6,375. A 20-foot wide and 20-foot deep key trench is located at the footprint of the embankment that extends to bedrock. The embankment was constructed without provision for handling of construction water. After completion of construction, extensive seepage was found on the right abutment. A limited grouting program was performed to reduce the seepage. The grouting program was relatively successful in reducing the seepage flow.

The existing service spillway is concrete lined with a capacity of 17,000 cubic feet per second. The spillway has a bathtub shaped ogee crest. The outlet works discharges into the spillway at about elevation 6,317.5.

The existing outlet works consists of a 36-inch diameter concrete pipe with an intake at elevation 6,332.7. The intake has two hydraulically operated gates.

1.3 RESERVOIR DRAINED FOR CONSTRUCTION

Lowering the water level to the level of the existing outlet works and draining the reservoir by pumping is the typical method for breaching a dam. Once the reservoir is drained the existing embankment can be breached to the level of the new outlet works. With this sequence the reservoir will remain empty for a two year construction period and the flows in Elkhead Creek will be passed through a temporary diversion and the new outlet works.

1.4 RESERVOIR LOWERED FOR CONSTRUCTION

An alternative to draining the reservoir is to retain a partial reservoir pool during construction. This allows for use of the reservoir and maintaining the fish population. This alternative requires operation of the reservoir level near the elevation of the existing outlet works.

1.5 DESIGN CRITERIA

Design criteria were developed as part of this study to prepare a conceptual design of the three selected alternatives.

Water diversion during construction was evaluated based on the routed flows (Ayres 1999) for Elkhead Creek.

Frequency:	2-year	5-year	10-year
Snow melt:	1,200 cfs	1,300 cfs	1,500 cfs
Rainfall:	21 cfs	40 cfs	425 cfs

Outlet sizing was based on:

- Operational releases of up to 360 cfs
- Emergency drawdown of five feet of the reservoir in five days
- Future use of the outlet works to provide flow to a hydroelectric facility
- Construction routing of up to 425 cfs

Spillway sizing was provided by Ayres and consisted of:

- Routed PMF of 29,991 cfs based on inflow PMF of 35,793 cfs (Ayres 2001a)
- 320 foot long ogee crest (Ayres 2001a)
- freeboard of 1 foot for the PMF flow
- depth of flow for PMF of 9 feet

The reservoir must be operated during construction to meet the demands of the water users, pass storm events, control risk to the construction contractor, and prevent failure of the existing structure.

Modeling of the reservoir and the basin using the Colorado River Decision Support System (CRDSS) indicates that discharges from the reservoir could be on the order of 15,000 acre-feet over a several month period. Based on this flow, we estimate daily flows on the order of 12 to 200 cfs. These flows could be maintained with a lowered reservoir. If the reservoir is drained, the inflow to the basin would be passed directly through the construction site without controls.

We have assumed that scheduling of the construction of the raise would avoid peak snowmelt runoff events. This would require the dam breach and outlet works to be completed between June of one year and May of the next year. This would limit the storm flow events to about 425 cfs for a 10-year storm event. There is not a state requirement for construction flows and the original dam was built without any provision for passing storm events during construction.

The planned raise for the Elkhead Dam and Reservoir includes the following design components:

- Foundation Grouting and Foundation Treatment
- Embankment Raise
- Spillway Replacement
- Outlet Works Replacement

In general, the future planned raise will increase the reservoir level from the current normal pool El 6,365 to El. 6,380, corresponding to a 15 feet raise. Accordingly, the embankment crest elevation will be raised from El 6,375 to El 6,390, as shown on Figure 1. The raised embankment will be capable of storing the PMF with one foot of freeboard. The existing spillway will be removed and replaced with a new spillway with an crest at El 6,380, and designed to pass the routed PMF flood. Two alternatives are being considered for the spillway: a concrete lined channel on the left abutment and a Roller Compacted Concrete spillway over the main embankment. For this study we assumed the left abutment spillway was the preferred alternative.

As a part of the raise, the outlet works will be replaced so that a new outlet works would allow the reservoir to be completely drained through an intake tower with multiple gates located at various elevations. Flows through the outlet structure will be discharged to a 72-inch outlet pipe and fixed cone valve. The following section describes in more detail the conceptual level designs for the various design components.

3.1 FOUNDATION GROUTING AND FOUNDATION TREATMENT

Foundation grouting will be necessary to provide additional cutoff of seepage through the foundation material due to the increased reservoir head. A very limited grouting program was conducted on the right abutment after the dam was constructed in an attempt to control excessive seepage. We do not feel this program was completely successful. We anticipate a foundation-grouting program will be required for both abutments and possibly the valley bottom. Due to the nature of the sandstone bedrock we have assumed that the grouting program would use a microfine cement to grout joints and fissures in the bedrock. The additional 30 feet of head that would result from lowering the reservoir and not draining it should not increase the complexity or cost of the grouting program. The additional reservoir head will only add 15 to 20 psi to the grouting pressure.

The toe of the existing embankment will also need to be removed to construct a new chimney drain. The contact at the abutment may require treatment. The foundation of the excavated toe area may require treatment. The stability of the excavated toe will require monitoring.

3.2 EMBANKMENT RAISE

The planned embankment raise will increase the existing crest elevation of 6,375 by 15 feet to El 6,390, as shown on Figure 2. The embankment will be raised using the downstream method of construction after the excavation of the top 15 feet and 2 feet off the downstream face of the existing embankment. A new 3-foot thick drain/filter will be placed on the existing downstream slope of the embankment to control seepage through the embankment, as shown on Figure 2. The embankment raise material will consist of sandy clays and clayey sands obtained from potential borrow areas No. 1 and 2, as shown on Figure 1. We have assumed the drain/filter material will be purchased from a local aggregate supplier.

Prior to construction of the raise, the foundation area beneath the raise area will require treatment. This may consist of removal of approximately five feet of material in the footprint of the raise. The construction of the embankment raise will start from the toe of the existing embankment and move towards the new crest. The new crest of the embankment will be 30 feet wide. Prior to the placement of the 3-foot thick drain filter material, the surface of the existing downstream slope will be excavated a minimum of 2 feet to remove all the vegetation growth and loose materials. The construction of the filter/drain material will proceed simultaneously with the construction of the embankment raise.

3.3 SPILLWAY REPLACEMENT

A new spillway and stilling basin will be constructed at the left abutment, as shown on Figures 3 and 4. The planned spillway will consist of a reinforced concrete channel and chute with a crest elevation of 6,380. The spillway will be capable of routing 30,000 cfs. The spillway will have a crest length of 320 feet. The spillway chute will have a width of 100 feet and a height of 10 feet.

The existing spillway will be demolished and backfilled as a part of the earthworks associated with the embankment raise. The debris from the demolition will be buried on site.

3.4 OUTLET WORKS REPLACEMENT

The existing outlet works will be replaced to allow almost complete draining of the reservoir, if needed. The existing outlet works, located at the left abutment, will be abandoned by grouting. The planned outlet works will include a multi-gated intake structure to allow for reservoir discharge at various elevations. The intake tower will have between four and six intakes. This will require a tower with a minimum inside dimension of nine feet by nine feet. We have assumed the lowest intake elevation will be located at El 6,308. The inlet structure will be a reinforced concrete tower with gates at various elevations as shown on Figure 5. The outlet pipe from the tower will consist of a 72-inch diameter concrete encased epoxy-lined steel outlet pipe. The downstream valve house will include necessary piping, controls, and a 48-inch fixed cone valve. A 72-inch pipe was selected for this study based on the 10-year rainfall event and the future potential for a hydroelectric plant attached to the outlet works.

We have developed three outlet works replacement alternatives.

- Drained Reservoir Outlet Works through Embankment (Alternative 1)
- Lowered Reservoir Outlet Works through Embankment (Alternative 2)
- Lowered Reservoir Outlet Works through Left Abutment (Alternative 3)

Alternative 1:

The outlet works in the Drained Reservoir Alternative 1 will consist of a new outlet pipe constructed through the embankment. In this alternative, the reservoir will be drained to about El. 6,308 and a small diversion dam with a diversion pipe will be constructed to allow for the construction of the new outlet works through the embankment. The embankment will be excavated, as shown on Figures 3 and 4, to allow for the placement of the outlet pipe. Upon completion of the placement of the outlet pipe, the excavated embankment will be backfilled with excavated materials supplemented by materials from the borrow sources. Upon completion of the lower portion of the intake tower, outlet pipe, and the outlet structure, the stream flows will be diverted into the new outlet pipe and the diversion pipe will be removed.

Alternative 2:

The outlet works in Alternative 2 will be constructed at the same location and elevation as the outlet works in Alternative 1. The reservoir will only be lowered to El. 6,333. This will require a cofferdam to retain the reservoir. We evaluated two cofferdam alternatives: a cellular cofferdam and an earth cofferdam. We estimated an earth cofferdam would require approximately 150,000 to 200,000 cubic yards of material. This quantity indicates a cellular cofferdam would be more cost effective. The cellular cofferdam would require a bypass pipe to allow stream and storm flows through the construction site. The cofferdam would consist of 12 to 15 interlocking steel sheetpile cells backfilled with gravel. The cofferdam would be removed after construction is completed.

Alternative 3:

In Alternative 3, the new outlet works will be located at the left abutment, as shown on Figure 3. In this case, the reservoir does not need to be drained, but will be lowered to about El 6,333, corresponding to the inlet of the existing outlet works. During the construction of the new outlet works, the existing outlet works will allow for the discharge of storm flows. The intake tower structure will be constructed in an excavation in the abutment. A portion of the abutment will be left in place during the construction of the new outlet works to retain the reservoir, as shown on Figure 6. This area will be excavated after the completion of the new outlet works construction. The new 72-inch diameter outlet pipe will be located in a 435–foot long, 9-foot diameter tunnel, as shown on Figure 6. The annular space between the pipe and the tunnel walls will be grouted.

3.5 FISH SEPARATION

The need for fish separation was first identified by Hydrosphere Resource Consultants (1995) in the Yampa River Basin, Recommended Alternative. The Yampa River and its tributaries are evolving with native fish being replaced by non-native fish. The Yampa River also contains endangered species that are protected by the Endangered Species Act of 1973. A program to implement recovery of endangered fish species in the upper Colorado River Basin has been established. The Recovery Action Plan identifies control options to reduce non-native fish escapement from Elkhead Reservoir. There are no current requirements to implement fish separation measures at the reservoir, but requirements may be necessary on future work at the reservoir. Permanent fish separation measures were not included in this evaluation since they do not affect the construction sequence. We have also assumed that fish separation would not be required during construction since there is a very low probability of an uncontrolled flow over the spillway during embankment construction.

The main design components associated with the raise, such as the foundation treatment, embankment raise, and spillway replacement are identical under the above alternatives.

The outlet works replacement alternatives have identical design components. However, the three alternatives are located at different locations that have a significant impact on the construction methodology and sequencing. The comparison of the construction methodologies and sequencing of the construction activities are presented in Table 4-1. The spillway has been excluded from the comparison since it does not have an impact on the construction sequence.

Table 4-1
Summary of Construction Sequence for Alternatives

Alternative 1 **Drained Reservoir**	**Alternative 2** **Lowered Reservoir** **Embankment Outlet**	**Alternative 3** **Lowered Reservoir** **Abutment Outlet**
Drain reservoir to 6,333	Drain reservoir to 6,333	Drain reservoir to 6,333
Pump reservoir to 6,308	Install cellular cofferdam	Excavate intake tower area
Remove riprap and top of dam	Fill cells of cofferdam	Construct tunnel portals
Breach dam	Remove riprap and top of dam	Bore tunnel
Install stream bypass	Breach dam	Line tunnel
Construct outlet works	Install stream bypass Construct outlet works	Construct intake tower Excavate channel to reservoir
Construct intake tower Divert creek to outlet works	Construct intake tower	Divert stream to outlet works
Develop borrow area and access	Divert stream to outlet works	Remove riprap and top of dam
Construct embankment	Develop borrow area and access	Develop borrow area and access
--	Construct embankment	Construct embankment

The advantages and disadvantages of the alternatives based on factors other than cost are presented in Table 4-2.

Table 4-2
Summary of Advantages and Disadvantages for Alternatives

Outlet Works Replacement Alternative	Advantages	Disadvantages
Drained Reservoir Alternative 1	Relatively easy excavation through the embankment Relatively common outlet pipe construction methodology through embankment Does not require specialty contractor Borrow areas within the reservoir	Does not provide fish separation and survival during construction Requires stream diversion Increased risk of flooding the embankment excavation area during construction Large dam breach necessary
Lowered Reservoir Alternative 2	Relatively easy excavation through the embankment Relatively common outlet pipe construction methodology Does not require specialty contractor	Requires difficult stream diversion Increased risk of flooding the embankment excavation area during construction Large dam breach necessary Borrow area requires reclamation
Lowered Reservoir Alternative 3	Does not require stream diversion, the existing outlet work will be used for flood routing Minimal embankment excavation. Cofferdam not necessary Dam breach not necessary	Requires a specialty contractor for the tunnel More difficult construction for intake tower due to constricted area Borrow area requires reclamation

The conceptual level cost estimate provided is intended as a tool for the evaluation of alternatives and to provide an economic analysis of the key components of the project. Development of design and cost were based on topographic data and information provided by the CRWCD. The construction cost provided is intended to be for "budget and comparison" and do not include cost for lands and damages, environmental permitting and mitigation, design contingencies, and owner costs.

The quantity estimates were prepared based on the conceptual level of design and the focus was placed on major features. Construction pricing was based on unit pricing from published and internally developed and maintained historical databases. The logic, methods, and procedures used were typical for the construction industry.

Since the cost estimating for this work is intended as a comparison between alternatives, a contingency and mobilization were not added. The key project components for each alternative are summarized in Table 5-1. The components are identified for site preparation, embankment, spillway, and outlet works.

Table 5-1
Summary of Key Project Components

	Unit of Measure	Alternative 1 Drained Reservoir	Alternative 2 Lowered Reservoir	Alternative 3 Lowered Reservoir
Site Preparation				
Haul Road	LF	1,400	3,700	3,700
Diversion and care of water	LS	1	1	1
Borrow area development	AC	-	20	20
Embankment				
Removal/excavation	CY	161,000	161,000	89,000
Embankment	CY	461,000	461,000	461,000
Drain Zone	CY	27,000	27,000	27,000
Grouting	LF	20,000	20,000	20,000
Instrumentation	LS	1	1	1
Spillway				
Excavation	CY	45,000	45,000	45,000
Concrete	CY	45,000	45,000	45,000

	Unit of Measure	Alternative 1 Drained Reservoir	Alternative 2 Lowered Reservoir	Alternative 3 Lowered Reservoir
Outlet Works				
Concrete	CY	1,700	1,700	450
Steel Pipe	LF	450	450	435
Tunnel	LF	-	-	435
Valve Building	LS	1	1	1

Based on the Key Project components and associated items, we have developed a cost for each alternative.

A comparison of the cost differential for Alternatives 2 and 3 compared to the base rate is shown on the table below.

Table 5-2
Summary of Construction Costs

	Base Case Alternative 1 Drained Reservoir	Alternative 2 Lowered Reservoir	Alternative 3 Lowered Reservoir
Site Preparation	--	$1,044,000	$169,000
Embankment	--	--	($485,000)
Spillway	--	--	--
Outlet Works	--	--	$549,000
Total, Cost Difference	--	**$1,044,000**	**$233,000**

The total cost for the alternatives differed by about $1,000,000. This difference is mainly due to the cofferdam required in Alternative 2. The outlet works tunnel used in Alternative 3 results in a cost of about $250,000 greater than the base case.

We have identified several issues that should be evaluated in design development for the project.

The location of the intake tower for Alternatives 1 and 2 should be further evaluated to determine the appropriate location. Placement of the tower at the center of the valley may not be preferable due to existing reservoir sediments.

The extent of borrow materials and their impact on land owners and the state park master plan should be studied. There is sufficient borrow material available, but the preferred area for its removal should be evaluated.

The extent of foundation grouting should be quantified. We have assumed a microfine cement will be necessary for grouting of the joints in the sandstone bedrock. It is unclear if grouting of the sandstone matrix is necessary.

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